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13. ABSTRACT
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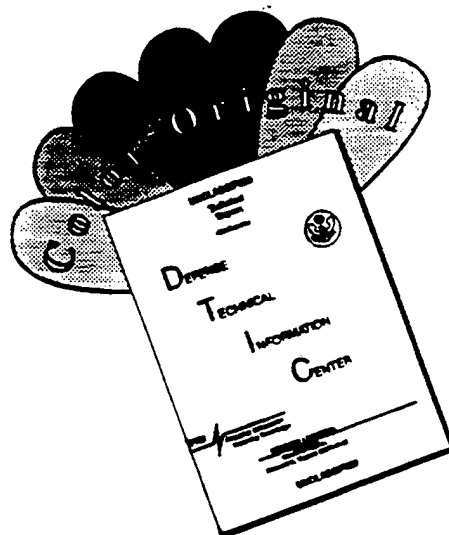
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SITE MODEL-BASED IMAGE EXPLOITATION

TYPE OF REPORT: TECHNICAL

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Site Model-Based Image Exploitation

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Abstract

This report describes the work done at the University of Maryland in collaboration with McDonnell Douglas Aerospace on site model-based image exploitation, during the period 3/1/95 – 7/31/95. The goals are (a) to use EO imagery obtained from a reconnaissance flight to build a detailed 3-D model of the target site, and (b) to use the site model to register and exploit images from an IR sequence obtained from a sensor mounted on a platform approaching the target site. The ultimate aim is the precise guidance of the platform based on a comparison of reference images generated from the site model and the IR images obtained by the platform itself.

1 Introduction

Several military and civilian applications could benefit greatly from the site-model based Image Exploitation (IE) techniques developed over the past few at the University of Maryland (e.g. [1]). McDonnell Douglas Aerospace is interested in using such techniques for the problem of terminal guidance of a moving platform. The goal is to enable a moving platform to home in on a precise location inside a target site. The platform is assumed to be equipped with an infra-red (IR) sensor, which continuously acquires a sequence of IR images of the target site. The idea is to compare the images in this sequence to "reference" images of the target site synthesized from assumed camera positions, and thus help the platform determine its own position and orientation relative to the target. The platform can then make the necessary adjustments to its motion in order to stay on the right trajectory with respect to the target.

One way to generate reference images is to build a 3-D model of the site, and then "render" the site from the desired viewpoint. The site model can be constructed using a set of reconnaissance images of the site obtained by an aircraft flying around the site.

In this report, we describe the work done at the University of Maryland in collaboration with McDonnell Douglas Aerospace during the period 3/1/95 – 7/31/95, as well as the work that is proposed to be carried out during the next two years on this project. We have made extensive use of the Radius Common Development Environment (RCDE) in this project. RCDE provides a user-friendly environment for site-model construction and image registration. Details about RCDE can be found in [5].

2 Input Data

The input data (listed in the ATG Reconnaissance Catalog) consists of the following:

(a) Images of the site taken from a reconnaissance aircraft

(b) Geocentric camera positions: latitude, longitude, and altitude

(c) Target-centered camera positions: range, azimuth (heading angle) and elevation (depression angle) w.r.t the target

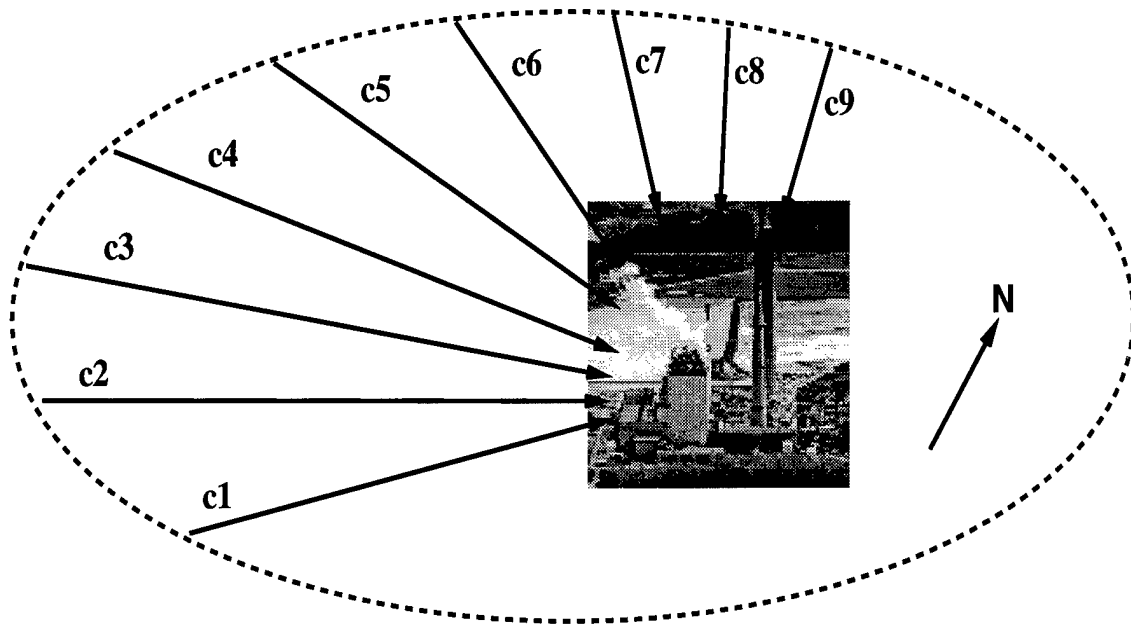(d) Camera internal parameters: field of view (FOV) and focal length (f)

Figure 1: Reconnaissance flight scenario.

(e) Geocentric coordinates of an aim point (target) in the site

In addition to the above, plan views and elevations of the site were used to obtain ground truth 3-D locations of control points in the site.

A typical reconnaissance flight scenario is shown in Fig. 1. This is based on the "C" sequence from the Labadie power plant data set. Typical reconnaissance images, again from the Labadie set, are shown in Fig. 2.

3 Calculation of camera positions relative to the target

This can be done in two ways, either using geocentric positions (Fig. 3), or using target-centered positions (Fig. 4). In the first case, all measurements of aircraft/camera positions are in absolute terms, independent of the site's location. In the second, all the measurements are w.r.t. the site under consideration. This provides a way of cross-checking the results. In the case of the Labadie data set, the results tallied to within 20 m.
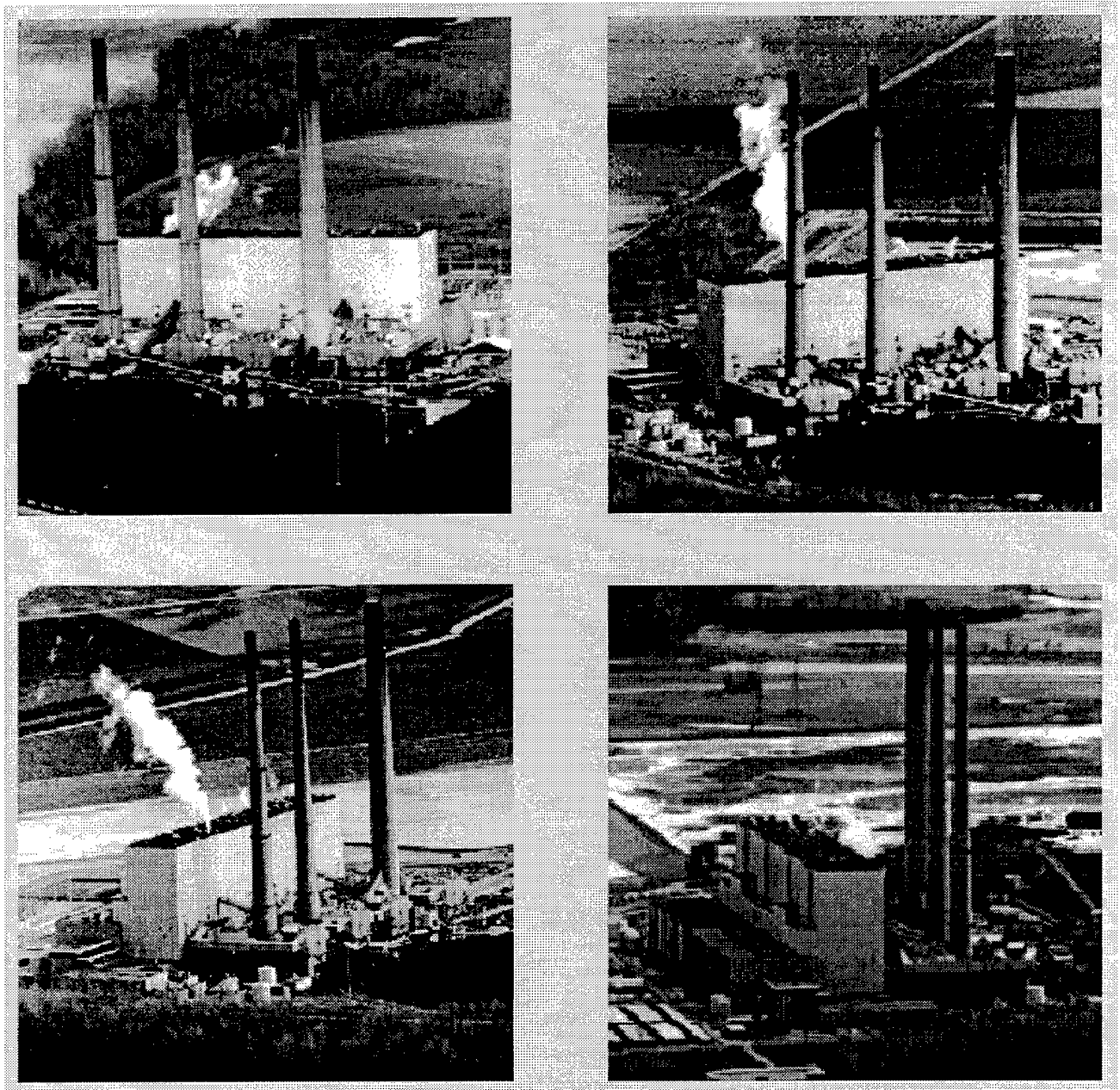
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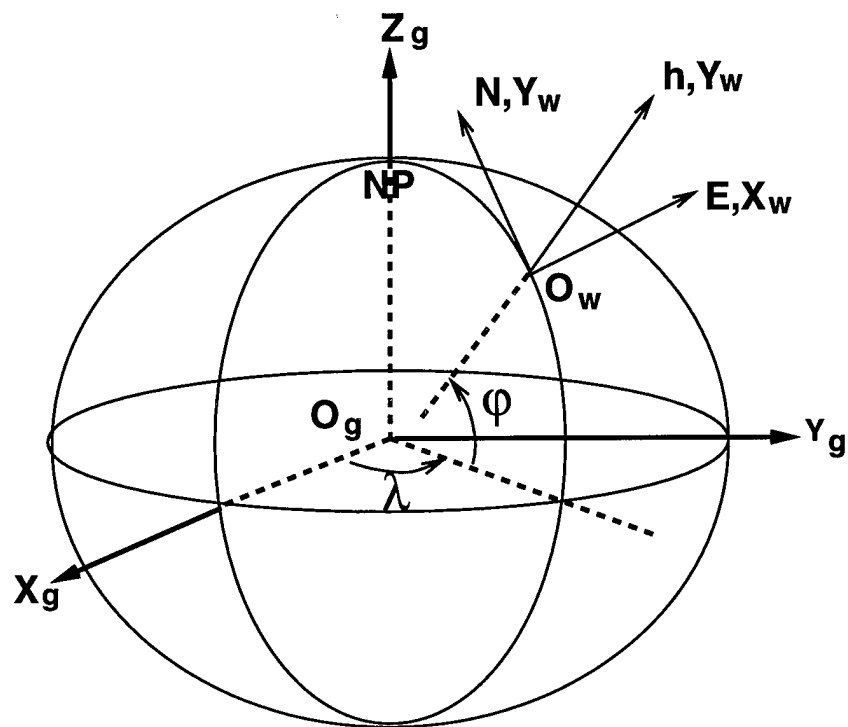Figure 2: Reconnaissance images of the Labadie power plant.
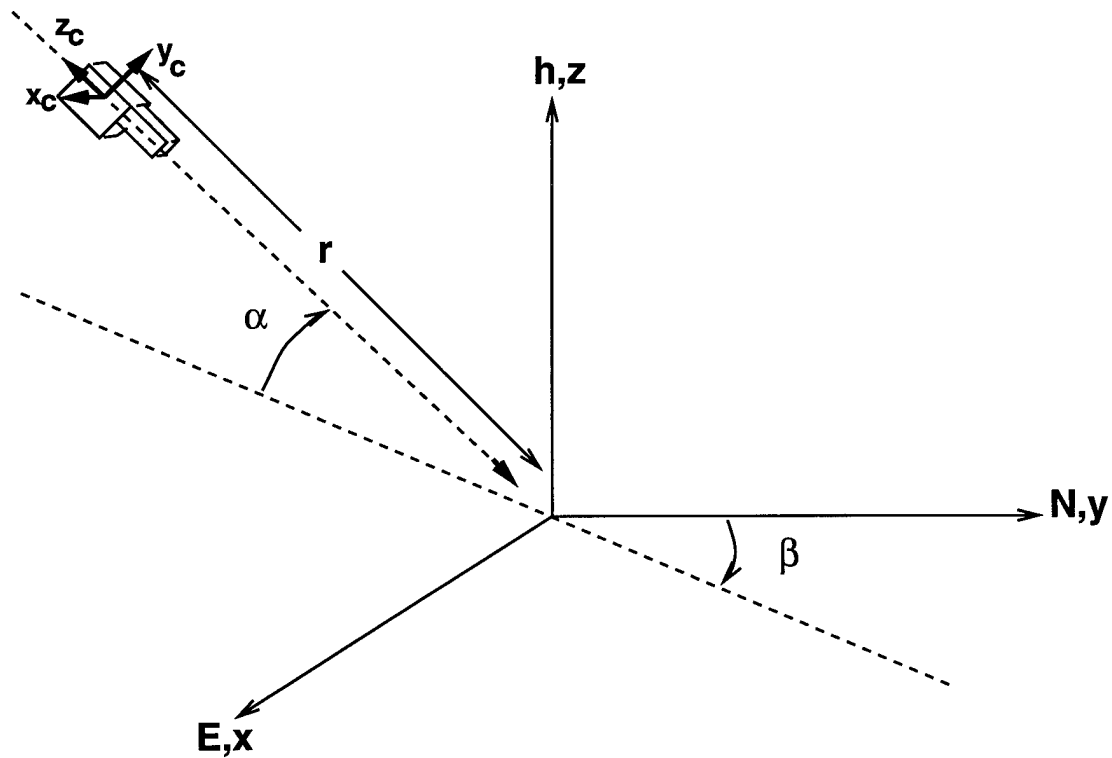
Figure 3: Geocentric coordinates

Figure 4: Elevation, range and heading

4

Using geocentric coordinates Consider two coordinate systems attached to the earth:

- The geocentric coordinate system (GCS): (O_g, X_g, Y_g, Z_g) with the origin at the center of the earth, the X_g axis passing through the Greenwich Meridian, and the Z_g axis passing through the north pole.

- The local vertical coordinate system (LVCS): (O_w, X_w, Y_w, Z_w) with its origin at some chosen ground level point at the target, and the X_w, Y_w and Z_w axes corresponding to the local north, local east and the local vertical directions, respectively.

The aim here is to express the camera position (specified in terms of its latitude, longitude and altitude) in the LVCS at the site. We choose the following sign conventions: (a) northern latitudes and eastern longitudes are considered to have positive signs and (b) altitudes above mean sea level are considered positive.

The camera's position is first expressed in geocentric Cartesian coordinates as follows. Let ψ, λ and h be, respectively, latitude, longitude and height. Let r_e be the radius of the earth. Then, from Fig. 3, the camera's position $\mathbf{p}_g$ can be written as

$$\mathbf{p}_g = \begin{bmatrix} (r_e + h)\cos(\psi)\cos(\lambda) \\ (r_e + h)\cos(\psi)\sin(\lambda) \\ (r_e + h)\sin(\psi) \end{bmatrix}$$

The above equation is used to obtain the position $\mathbf{p}_g$ of the camera as well as the position $\mathbf{p}_0$ of the aim point in the site. The position $\mathbf{p}_w$ of the camera in the LVCS can then be obtained by a translation and two rotations, as

$$\mathbf{p}_w = \mathbf{R}_{(x,\pi/2-\psi)}\mathbf{R}_{(z,\pi/2+\lambda)}(\mathbf{p}_g - \mathbf{p}_0)$$

where

$$\mathbf{R}_{(z,\pi/2+\lambda)} = \begin{bmatrix} \cos(\pi/2+\lambda) & \sin(\pi/2+\lambda) & 0 \\ -\sin(\pi/2+\lambda) & \cos(\pi/2+\lambda) & 0 \\ 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} -\sin(\lambda) & \cos(\pi/2+\lambda) & 0 \\ -\cos(\lambda) & -\sin(\lambda) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{R}_{(x,\pi/2-\psi)} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos(\pi/2-\psi) & \sin(\pi/2-\psi) \\ 0 & -\sin(\pi/2-\psi) & \cos(\pi/2-\psi) \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \sin(\psi) & \cos(\psi) \\ 0 & -\cos(\psi) & \sin(\psi) \end{bmatrix}$$

Using target-centered coordinates   The aim here is to obtain the camera's position in the LVCS, given its azimuth β, elevation α and range r w.r.t the target, measured as shown in Fig. 4. We choose the following notation:

- β is the azimuth angle measured in the McDonnell Douglas data from the Y axis clockwise (i.e. east of north). Note that the azimuth measures the angle between the camera's *pointing direction* and the north. To determine the camera's *position*, this azimuth should be offset by π.

- α is the elevation angle measured downwards from the horizontal.

$$\mathbf{p} = \begin{bmatrix} r\cos(\alpha)\cos(-\pi/2-\beta) \\ r\cos(\alpha)\sin(-\pi/2-\beta) \\ r\sin(\alpha) \end{bmatrix} = \begin{bmatrix} -r\cos(\alpha)\sin(\beta) \\ -r\cos(\alpha)\cos(\beta) \\ r\sin(\alpha) \end{bmatrix}$$

4   Computing the exterior orientation of the camera

An initial exterior orientation of the camera must be specified in the conformal photogrammetric representation in the RCDE. We describe the successive transformations leading to this representation.

Attach a right handed local vertical coordinate system to the site (LVCS) with the Y axis oriented in the north direction, the X axis pointing toward the east and the Z axis is in the positive vertical direction. The following derivation assumes that there is no camera roll. If roll is small, the derivation in this section will give results of sufficient accuracy to perform resection. However, if roll is significant, the results in the next section should be used.

In order to align the LVCS to the camera-centered coordinate system (CCCS), we must successively apply the following axis rotations:
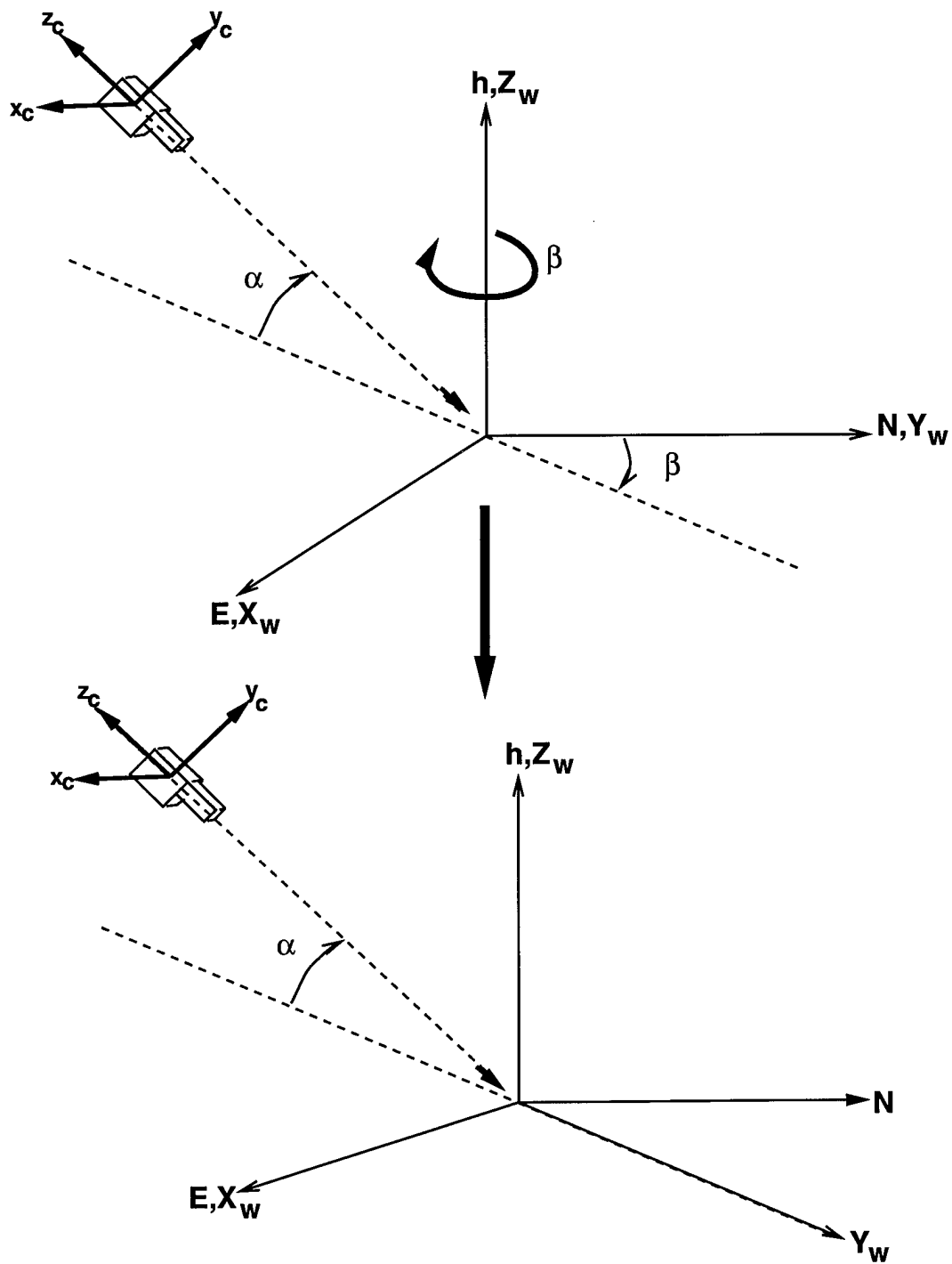
6

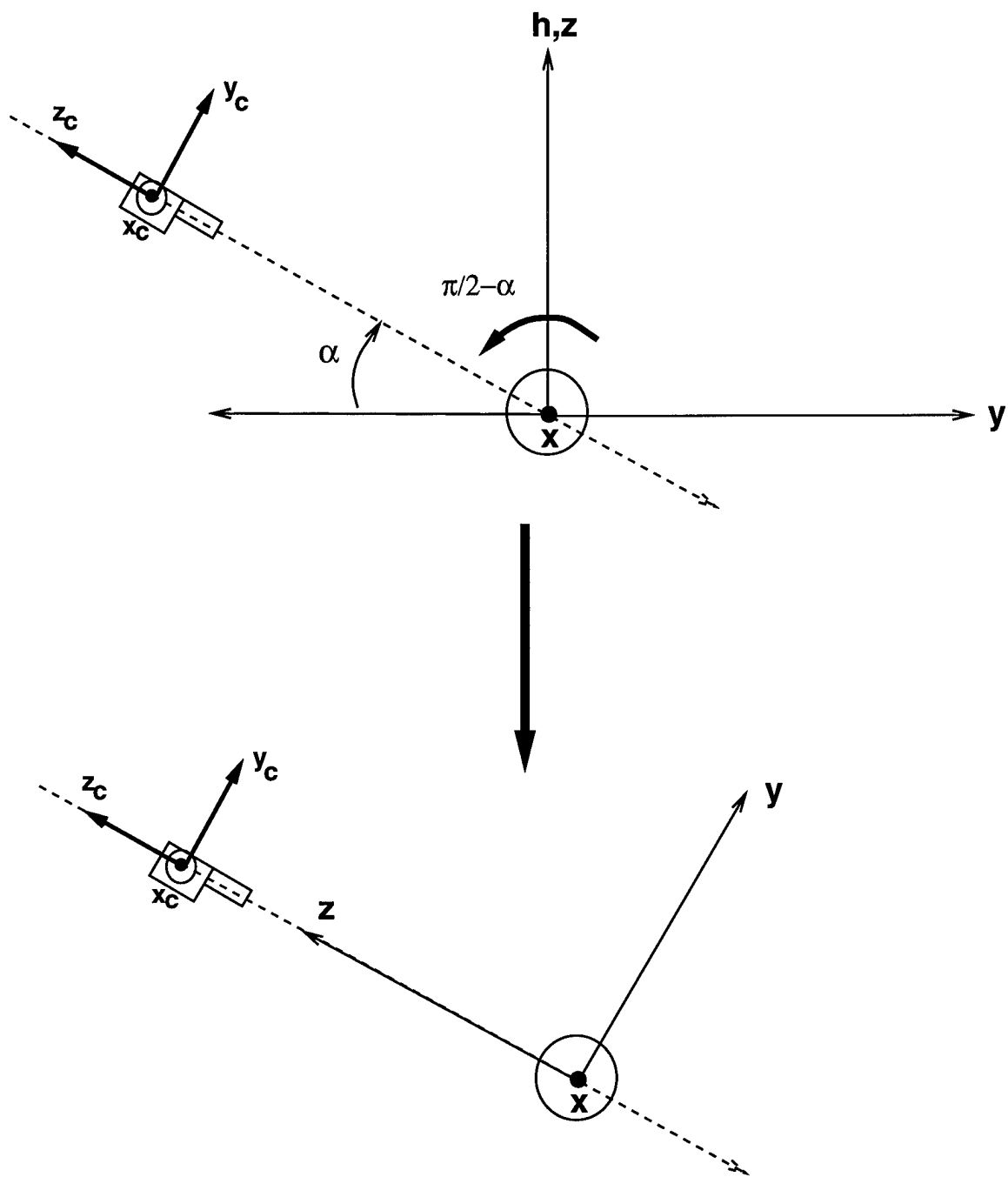Figure 5: Rotation around the z-axis by $-\beta$

Figure 6: Rotation around the x-axis by $\pi/2 - \alpha$

1. $\mathbf{R}_{(z,-\beta)}$: rotation by an angle β clockwise around the vertical Z axis to align the Z-axis of the CCCS with the YZ plane of the LVCS (Fig. 5).

2. $\mathbf{R}_{(x,\frac{\pi}{2}-\alpha)}$: rotation clockwise around the resulting X-axis to align the two Z axes (Fig. 6).

We have

$$\mathbf{R}_{(z,-\beta)} = \begin{bmatrix} \cos(\beta) & -\sin(\beta) & 0 \\ \sin(\beta) & \cos(\beta) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{R}_{(x,\frac{\pi}{2}-\alpha)} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \sin(\alpha) & \cos(\alpha) \\ 0 & -\cos(\alpha) & \sin(\alpha) \end{bmatrix}$$

Then $\mathbf{R} = \mathbf{R}_{(x,\frac{\pi}{2}-\alpha)}\mathbf{R}_{(z,-\beta)}$, i.e.

$$\mathbf{R} = \begin{bmatrix} \cos(\beta) & -\sin(\beta) & 0 \\ \sin(\alpha)\sin(\beta) & \sin(\alpha)\cos(\beta) & \cos(\alpha) \\ -\cos(\alpha)\sin(\beta) & -\cos(\alpha)\cos(\beta) & \sin(\alpha) \end{bmatrix} \tag{1}$$

On the other hand, RCDE uses the conformal representation to relate the world and camera coordinate systems. In this case the relationship between (x_w, y_w, z_w) and (x_c, y_c, z_c) is given by

$$\begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix} = \mathbf{R}_z(\kappa)\,\mathbf{R}_y(\phi)\,\mathbf{R}_x(\omega) \begin{pmatrix} x_w - x_o \\ y_w - y_o \\ z_w - z_o \end{pmatrix}$$

$$= \begin{pmatrix} \cos\kappa & \sin\kappa & 0 \\ -\sin\kappa & \cos\kappa & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\phi & 0 & -\sin\phi \\ 0 & 1 & 0 \\ \sin\phi & 0 & \cos\phi \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\omega & \sin\omega \\ 0 & -\sin\omega & \cos\omega \end{pmatrix} \begin{pmatrix} x_w - x_o \\ y_w - y_o \\ z_w - z_o \end{pmatrix}$$

9

$$
= \mathbf{R} \begin{pmatrix} x_w - x_o \\ y_w - y_o \\ z_w - z_o \end{pmatrix} \tag{2}
$$

where

$$
\mathbf{R} = \begin{pmatrix} \cos\phi\cos\kappa & \sin\omega\sin\phi\cos\kappa + \cos\omega\sin\kappa & -\cos\omega\sin\phi\cos\kappa + \sin\omega\sin\kappa \\ -\cos\phi\sin\kappa & -\sin\omega\sin\phi\sin\kappa + \cos\omega\cos\kappa & \cos\omega\sin\phi\sin\kappa + \sin\omega\cos\kappa \\ \sin\phi & -\sin\omega\cos\phi & \cos\omega\cos\phi \end{pmatrix} \tag{3}
$$

Comparing the expression of $\mathbf{R}$ in Eqs. 1 and 3,

$$
\omega = \tan^{-1}\left(\frac{\cos(\alpha)\cos(\beta)}{\sin(\alpha)}\right) \tag{4}
$$

$$
\phi = -\sin^{-1}\left(\cos(\alpha)\sin(\beta)\right) \tag{5}
$$

$$
\kappa = -\tan^{-1}\left(\frac{\sin(\alpha)\sin(\beta)}{-\cos(\phi)}, \frac{\cos(\beta)}{\cos(\phi)}\right) \tag{6}
$$

where $\tan^{-1}(y, x)$ is the four-quadrant inverse tangent of (y/x).

5 Computing roll

After performing these two rotations, the Z axis and the XY planes of the two coordinate systems will be aligned. A further rotation around the Z-axis is required to account for camera roll. The determination of the camera roll angle γ (measured clockwise around the Z-axis) is described in [3]. Once this angle is known, a final transformation $\mathbf{R}_{z,-\gamma}$ is needed, defined by

$$
\mathbf{R}_{z,-\gamma} = \begin{bmatrix} \cos(\gamma) & \sin(\gamma) & 0 \\ -\sin(\gamma) & \cos(\gamma) & 0 \\ 0 & 0 & 1 \end{bmatrix}
$$

Therefore,

$$
R = \begin{bmatrix} \cos(\gamma)\cos(\beta) + \sin(\gamma)\sin(\alpha)\sin(\beta) & -\cos(\gamma)\sin(\beta) + \sin(\gamma)\sin(\alpha)\cos(\beta) & \sin(\gamma)\cos(\alpha) \\ -\sin(\gamma)\cos(\beta) + \cos(\gamma)\sin(\alpha)\sin(\beta) & \sin(\gamma)\sin(\beta) + \cos(\gamma)\sin(\alpha)\cos(\beta) & \cos(\gamma)\cos(\alpha) \\ -\cos(\alpha)\sin(\beta) & -\cos(\alpha)\cos(\beta) & \sin(\alpha) \end{bmatrix}
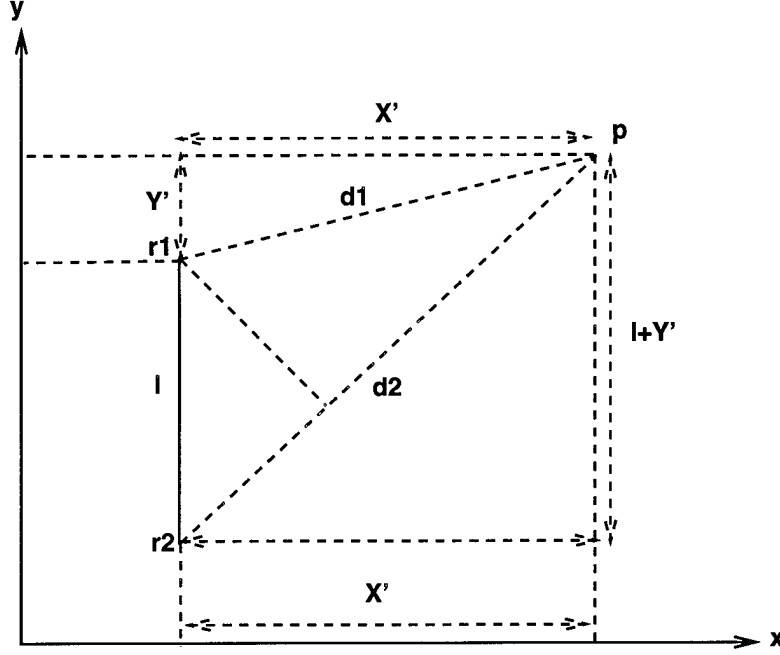$$

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Figure 7: Measuring control point locations from the site plan

The values of ω and ϕ are the same as before, but the value of κ changes to

$$\kappa = -\mathrm{Tan}^{-1}\left(\frac{-\sin(\gamma)\cos(\beta) + \cos(\gamma)\sin(\alpha)\sin(\beta)}{-\cos(\phi)}, \frac{\cos(\gamma)\cos(\beta) + \sin(\gamma)\sin(\alpha)\sin(\beta)}{\cos(\phi)}\right)$$

6 Obtaining control points from the site plan

A simple scheme for obtaining control points from the site plan is illustrated in Fig. 7. The following are the steps to be followed:

1. Choose two reference points on the plan view, lying on a line parallel to the *site north* direction, which is the principal direction in which the buildings are oriented. Measure the distance l between them.

2. Measure d_1, d_2, and Z for all selected control points (d_1 and d_2 from the plan view, and Z from the elevation). Choose the origin p_0 of the LVCS as one of the control points.

3. Convert from d_1, d_2 to $|X'|$, Y'. The relevant formulae are

$$Y' = \frac{1}{2l}(d_2^2 - d_1^2 - l^2) \tag{7}$$

$$|X'| = \sqrt{d_1^2 - Y'^2} \tag{8}$$

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4. Equation 8 gives only the absolute value of X'. Set the sign of X' by visual inspection.

5. The $\tilde{p} = (X', Y', Z)$ obtained from the previous steps will be with respect to a coordinate system in which the y-axis is the plant north, whereas in the LVCS the y-axis is (in our convention) the geographic north, at an angle ϕ with the plant north. We therefore need to rotate the original coordinates to bring them into the LVCS. Further, the origin $\tilde{p}_0$ may be shifted from the actual origin of the LVCS (p_0), and hence we need to make a translation to bring the coordinates p_0 to $(0, 0, 0)$. For any point $\tilde{p}$ previously measured, the conversion is

$$p = R'(\tilde{p} - T)$$

where

$$R = \begin{bmatrix} \cos(\phi) & \sin(\phi) & 0 \\ -\sin(\phi) & \cos(\phi) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

and

$$T = \tilde{p}_0$$

7 Registration and Resection

This section outlines the procedure used for registering images to a site model using RCDE. More details can be found in [3].

The first step is the creation of a "3-D world", which defines the LVCS associated with the site. The origin of the LVCS is chosen to be some central point in the site for which ground truth is available. To register an image, a camera object is created and associated with it. This has two main components, internal and external camera parameters. Internal parameters are focal length the location of the principal point, and a parameter that indicates the type of projection - perspective, orthographic or something intermediate.[1] These are usually available, or can be easily determined. External parameters are the position and

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[1]RCDE provides a more sophisticated method for camera modeling, called the FBIP representation. This method is applicable in cases where the traditional pinhole model is not accurate enough.
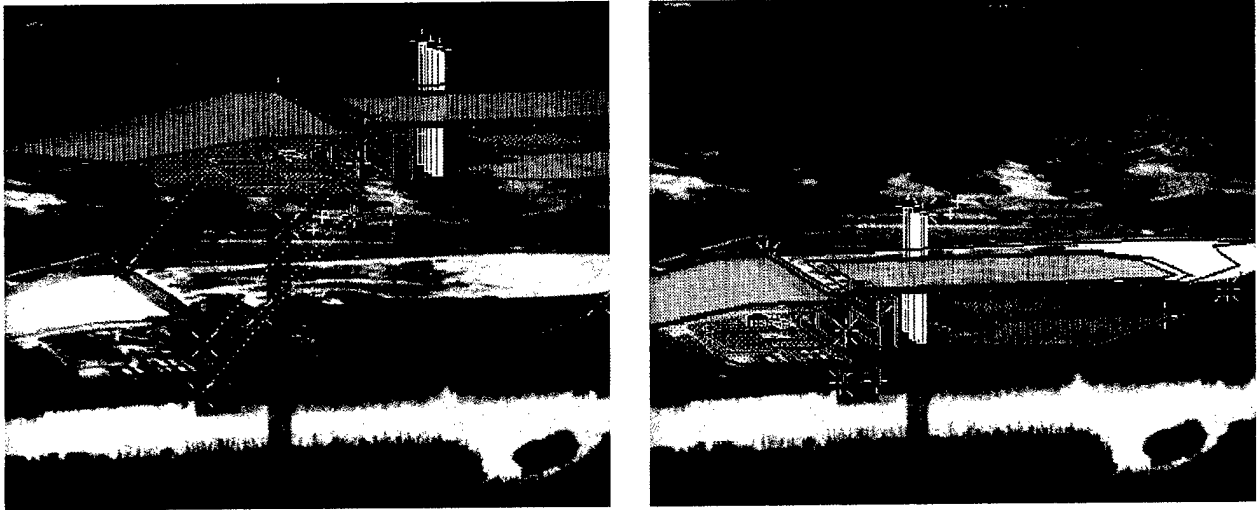
Figure 8: Example of resection: on the left we show the site model projected on an unregistered image, and on the right the result after resection.

orientation of the camera in 3-D. These parameters are determined as explained in Sections 3 and 4. However, they can be calculated only approximately, and are not accurate enough to be used directly for registration. To determine accurate external camera parameters, RCDE provides a mechanism, called "resection" in photogrammetric terminology, which is essentially an iterative optimization of the external parameters given a set of 3-D control points and their locations in the image. The idea is to minimize the discrepancy between the image positions of the control points as predicted by the camera model, and their actual positions as observed in the image. The approximate parameters determined as described earlier are used to initialize the optimization. An example of resection is shown in Fig. 8.

8 Building the site model

In this section, we detail the methods used to construct a site model in RCDE, given a set of registered reconnaissance images of the site. It is assumed that a plan view of the site is
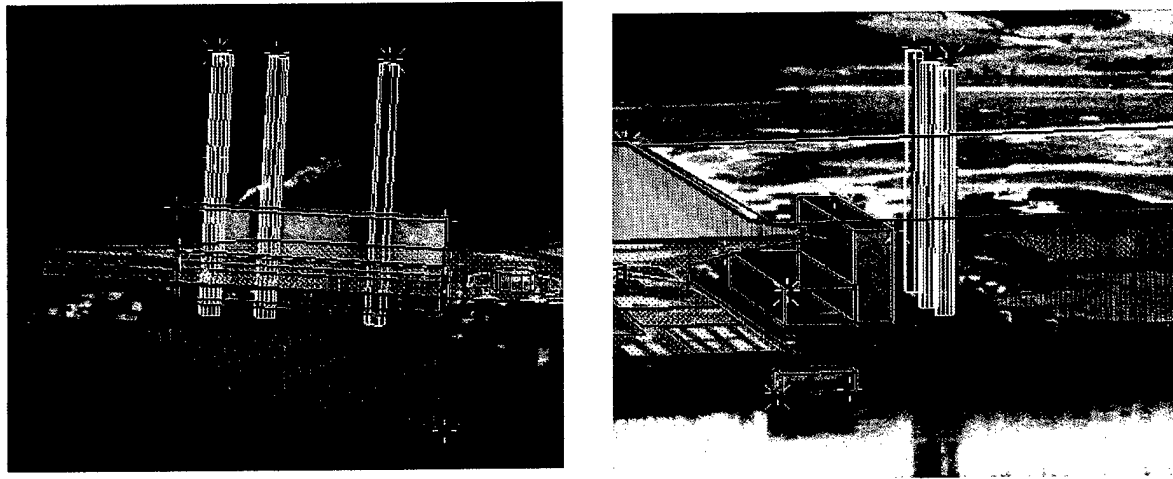
13

Figure 9: Example of a site model: the Labadie power plant site, shown from two different viewpoints. Not all site model objects are shown.

also available in the form of an image, and that this image has been registered to the LVCS.

Currently, site model construction is done manually. Each type of site model object is handled slightly differently, and a certain amount of experience is needed to construct a site model that accords well with the reconnaissance images. Let us consider the most common type of site model object, the rectangular box used to model buildings. A box is defined by its size parameters (length, breadth, height), as well as its location and orientation in 3-D. RCDE allows the creation of box objects, and their modification by varying the size, position and orientation parameters. Most buildings are vertical, and their images in the plan view appear as rectangles. The logical place to start, then, is the plan view (Fig. 10). A box is created, and its horizontal dimensions and position are modified until it fits the rectangular outline of the building it is intended to model. Now we look at a different image, and see whether the box fits the building in it. If not, we make the necessary adjustments to the box's parameters until a good fit is obtained. This procedure is then repeated for a few
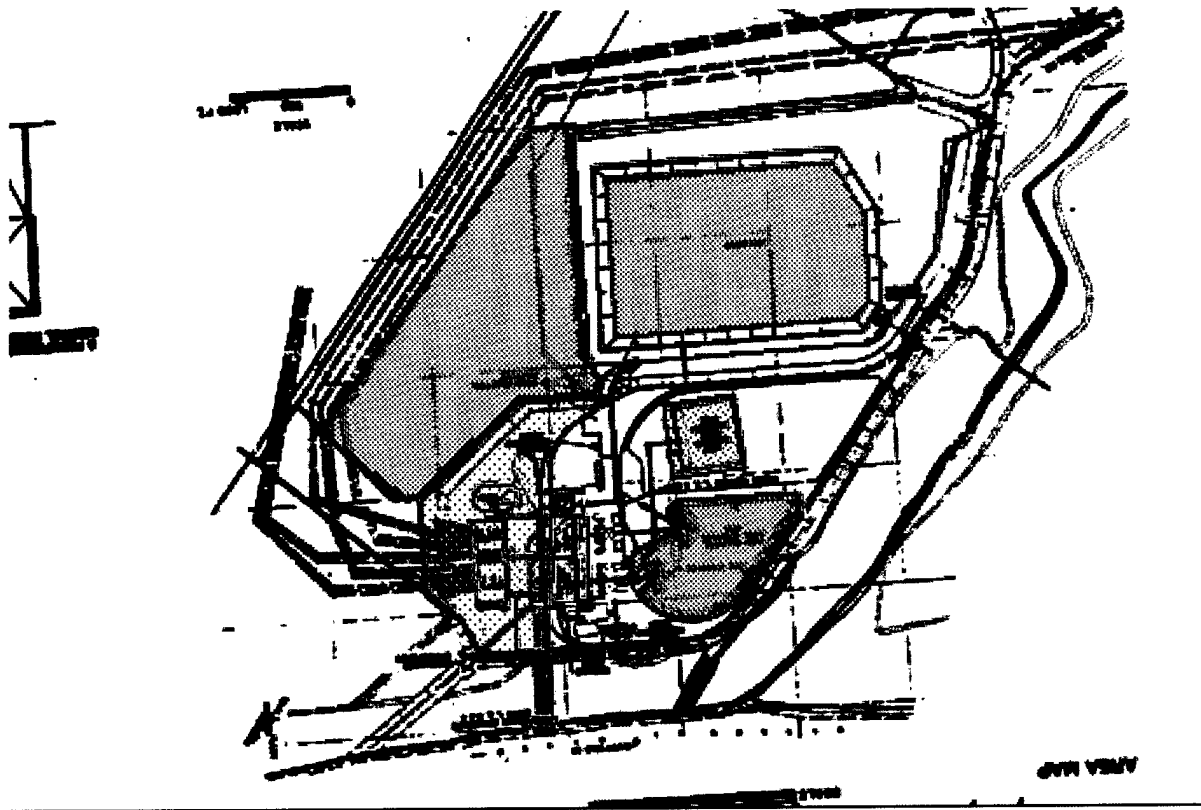
Figure 10: Plan view of the Labadie site, with the site model superimposed.

more images from the reconnaissance set, until the box fits the building equally well from all views.

Other site model objects of interest are cylinders, roads, 2-D and 3-D closed curves, etc. The procedure for constructing them can again be started with the plan view, and can then be refined with the help of a few other images. More details on site model construction using RCDE can be found in [3]. The site model constructed for the Labadie power plant is shown in Fig. 9.

9 Reference image generation

Given a 3-D site model, images of the site can be synthesized from assumed camera positions. In RCDE, a "sun ray" vector is first created for the site, indicating the direction of illumination. A rendered image can then be generated assuming a Lambertian scattering model. An example is shown in Fig. 11.
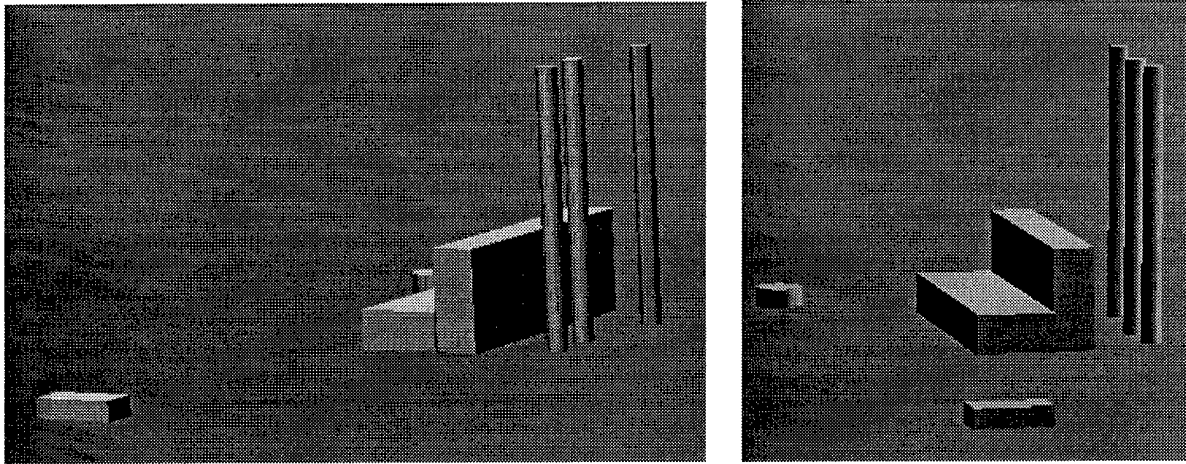
Figure 11: Example of rendering: two synthesized views of the Labadie site.

10 Future Work

The work described so far has been implemented and tested on the Labadie data set. While the results are satisfactory, the goal of terminal platform guidance requires the acceleration and/or automation of some of the steps involved. We plan to concentrate on the following two areas.

10.1 Fast site model construction

Site model construction using RCDE in its present form is slow and laborious, since all the work is done manually. A semi-automatic scheme for rapid construction of specific types of site model objects will be explored. For instance, boxes could be fit to rectangular buildings automatically by means of an optimization algorithm once the operator has identified the corresponding corners in the reconnaissance images (for instance, see [4]). For irregular objects such as rivers (represented geometrically by 2-D or 3-D ribbons), the operator could

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be asked to locate the object approximately in one image. An active contour algorithm could then be used to automatically track and delineate the object.

10.2 Dynamic registration

The registration of the IR sequence to the site model can be greatly enhanced by using a dynamic model for the motion of the platform. We can then draw upon the large number of recursive techniques that have been developed for motion analysis (e.g. [2]). The motion of the platform is assumed to be smooth to an arbitrary order (constant velocity, constant acceleration, etc.). A state-space representation is used to represent the time-evolution of the motion of the platform and its position in the LVCS. The parameters of the platform's motion constitute the elements of the state vector. Using the dynamic state space model, the positions of salient points from the site model (for instance, building corners) can be predicted in the image, and their true positions can be searched for within a small search areas centered around the predicted positions. The size of this search area is based on the uncertainty in the prediction. An extended Kalman filter is used to estimate the motion parameters.

An interesting feature of this scheme is that new features from the scene can be tracked, and their positions in the LVCS automatically estimated, as in [2]. This enables the automatic refinement of the site model. The importance of this is that the original site model, based on images taken from a reconnaissance aircraft typically flying at a range of several kilometers from the target, loses its relevance as the platform approaches the target. Features from the original site model disappear, and new, "unknown" features appear in the image. The recursive filtering paradigm enables us to localize these new features and add them to the site model.

References

[1] P. Burlina, R. Chellappa, C. Lin, and X. Zhang, "Context based exploitation of aerial imagery," in *Proc. Workshop on Context Based Vision*, (Cambridge, MA), June 1995.

[2] S. Chandrashekhar and R. Chellappa, "Passive navigation in a partially known environment," in *IEEE Workshop on Visual Motion*, (Princeton, NJ), pp. 2–7, Oct. 1991.

[3] R. Chellappa, Q. Zheng, L. Davis, C. Lin, X. Zhang, K. Rodriguez, and A. Rosenfeld, "Site Model Based Image Registration and Change Detection," tech. rep., Center for Automation Research, University of Maryland, College Park, 1994.

[4] C. McGlone, "Bundle adjustment with object space geometric constraints for site modeling," in *Proceedings of the SPIE, Vol. 2486: Integrating Photogrammetric Methods with Scene Analysis and Machine Vision II*, (Orlando, Florida), pp. 25–36, Apr. 1995.

[5] J. Mundy, R. Welty, L. Quam, T. Strat, W. Bremner, M. Horwedel, D. Hackett, and A. Hoogs, "The RADIUS Common Development Environment," in *Proc. DARPA Image Understanding Workshop*, (San Diego, CA), pp. 215–226, Jan. 1992.